8

Greenhagen, Andrew

From: Gilmore, Tyler J <Tyler.Gilmore@pnnl.gov>
Sent: Thursday, January 23, 2014 5:22 PM
To: McDonald, Jeffrey
Cc: Greenhagen, Andrew; Bayer, MaryRose
Subject: Re: IR4_01-14-2014 for the FGA permit applications
Attachments: EPA_IR4_for_FG-RPT-017-Final.pdf

Jeff,
Attached are our responses to your 1/14 request for additional information. Please call if you have any questions.
Thanks
Tyler

Tyler Gilmore
Battelle Manager FutureGen Storage Site
Pacific Northwest National Laboratory
509 371 7171
509 430 9898 (cell)

01-14-2014: Email from Jeff McDonald (U.S. EPA Region 5) to Tyler Gilmore (Alliance): "Informal Request (IR) #4 (IR4_01-14-2014)"

Requests based on the text application

IR #	Subject	Page	Doc. Sec.	Par.	EPA Comment / Question / Request	FutureGen Response	Footnote / Reference Citation
01-14-2014_1	Construction and Operations - Annulus fluids	4.13	4.2.5		""Actual products may vary from those described above." This language is problematic in that the regulations require that the Director approve the annular fluid. Although we are not precluding any potential changes in the future, please provide the single, anticipated choice for this matter so that the EPA can decide if it meets the regulatory requirements."	The annular fluid system is designed for a common salt solution (e.g., potassium chloride, calcium chloride, sodium chloride) with a weight ranging from approximately 8.5 to 9.5 lb/gal.	
01-14-2014_2	Construction and Operations - Open vs cased inj. Zone	4.15 to 4.18	4.2.7 and 4.2.8		"Although you may be considering both open-hole completions or cased-hole completions, a decision on this matter needs to be made before any permit decision. Although we are not precluding any potential changes in the future, please provide the single, anticipated choice for this matter so that the EPA can decide if it meets the regulatory requirements."	Based on recommendations from our drilling experts, the Alliance has decided to use a perforated cased-hole completion for the CO_2 injection zones. The cased borehole will provide better long-term stability for the injection well. The pressure and injection rates determined from the numerical simulations will not change whether the injection wells are cased and perforated, or open to the formation. See Appendix B, **Figure 4.4** for an enhanced schematic of a CO_2 injection well with a cased-hole injection zone.	
01-14-2014_3	Construction and Operations - Pre-operational Formation Testing Plan	4.19	4.2.9		"The EPA would like to see more details on the pre-operational testing plan discussed in this section. Some data that will come out of this formation testing (e.g., analysis of Mt. Simon, St. Peter and New Richmond formations) are important in review."	Sections **4.2.9**, **4.2.10**, and **4.2.11** of the Supporting Documentation of the UIC Permit Applications have been updated and two sections (**4.2.12** and **4.2.13**) have been added to provide more information regarding the pre-operational testing plan. These sections are included in Appendix A.	
01-14-2014_4	Construction and Operations - Stimulation Plan	4.22	4.4		"A stimulation plan has not been submitted at this point. If one is submitted soon, then it can be evaluated prior to any permit decision. If a permit is issued, a stimulation plan can be included in the record. If a stimulation plan is submitted after a permit decision, then a permit modification (assuming a permit is issued) would be required to add a stimulation plan."	There are no plans to stimulate the injection zone in order to enhance the injectivity potential. Hence, no stimulation plan will be submitted.	

IR 4

(8)

IR 4

01-14-2014: Email from Jeff McDonald (U.S. EPA Region 5) to Tyler Gilmore (Alliance): "Informal Request (IR) #4 (IR4_01-14-2014)"							
Requests based on the text application							
IR #	**Subject**	**Page**	**Doc. Sec.**	**Par.**	**EPA Comment / Question / Request**	**FutureGen Response**	**Footnote / Reference Citation**
01-14-2014_5	Construction and Operations – length of casing in CO_2 injection wells	4.17 and 4.18	4.2.8		"There are apparent typos on figures 4.4 and 4.5. On those, it lists 3400' of 7" casing. Since the production casing has to at least be through the top of the Eau Claire at 3426', we know this is wrong. The amount of 7" should also vary based upon the type of completion being evaluated (i.e., a cased hole will have approx. 6000' of 7" casing).	Figures 4.4 and 4.5 in the UIC Permit and RAI1_10-31-2013, Appendix D, have the correct total length of 7-in.-diameter production casing listed on the figures. <u>Total 7–in.- diameter production casing for cased-hole completion</u>: 3,400-ft carbon steel casing + 2,604-ft or 3,604-ft stainless steel casing = 6,004 ft or 7,004 ft <u>Total 7–in,-diameter production casing for open-hole completion</u>: 3,400-ft carbon steel casing + 550 ft stainless steel casing = 3,950 ft These may have been missed due to the small font size on the figures and their raster image resolution within the PDF file (converted from a Word file). However, as stated in response 01-14-2014_2 above, the Alliance has decided to use a perforated cased-hole completion for the CO_2 injection zone in each of the CO_2 injection wells. See Appendix B, **Figure 4.4**, for an enhanced schematic of a CO_2 injection well with a cased-hole injection zone. For consistency, enhanced **Figure 6.1** (Diagram of Cased Injection Well After Plugging and Abandonment) is also included in Appendix B.	

Appendix A

IR 01-14-2014_3

Additional Information Regarding

Construction and Operations

and

Pre-operational Formation Testing Plan

Sections 4.2.9, 4.2.10, 4.2.11, 4.2.12, and 4.2.13 of UIC Permit Supporting Documentation

4.2.9 Pre-Operational Formation Testing

The pre-operational formation testing program will be implemented to obtain an analysis of the chemical and physical characteristics of the injection zone and confining zone(s) that meets the testing requirements of 40 CFR 146.87 and well construction requirements of 40 CFR 146.86. The pre-operational testing program will include a combination of logging, coring, formation geohydrologic testing (e.g., a pump test and/or injectivity tests), and other activities during the drilling and construction of the CO_2 injection well.

The pre-operational testing program will determine or verify the depth, thickness, mineralogy, lithology, porosity, permeability, and geomechanical information of the Mount Simon Sandstone (CO_2 injection zone), the overlying Eau Claire Formation (confining zone), and other relevant geologic formations. In addition, formation fluid characteristics will be obtained from the Mount Simon Sandstone to establish baseline data against which future measurements may be compared after the start of injection operations. The results of the testing activities will be documented in a report and submitted to the EPA after the well drilling and testing activities have been completed but before the start of CO_2 injection operations.

Before drilling the injection wells, a vertical pilot hole will be drilled at the injection well location through the Mount Simon Formation to the Precambrian basement to collect pre-operational characterization and testing data for the injection wells. After completing the characterization and testing in the vertical pilot hole, the borehole will be plugged (cemented) from total depth to the kick-off point (approximate depth of 3,200 ft bgs) and converted to one of the horizontal injection wells. Additional selected pre-operational testing will be conducted within one or more lateral boreholes.

4.2.10 Wireline Logging

Open-borehole logs will be run to obtain densely spaced, in situ, structural, stratigraphic, physical, chemical, and geomechanical information for Mount Simon Sandstone, the Eau Claire confining zone, and other key formations. Open-borehole characterization logs will be obtained at the surface casing end point, the intermediate casing end point, and at the long-string casing end point (i.e., total borehole depth) in the vertical pilot borehole. Open-borehole wireline logs will not be run in the 30-in.-diameter conductor casing borehole because logging tools are not suited for this large-diameter hole size. As detailed in Table 4.14, open-borehole logs will include caliper, gamma, spontaneous potential (or brine formation equivalent), resistivity, neutron, density, photoelectric cross-section, sonic (full waveform), nuclear magnetic resonance, resistivity-based and/or acoustic-based micro-image, and gamma spectroscopy logs.

Data generated from the extensive open-hole wireline program will be used in conjunction with core analysis data and in situ hydrologic test data to support estimates of mechanical properties (grain density, porosity, and compressibility), hydraulic properties (permeability), thermal properties (thermal conductivity and specific heat capacity) for rocks contained within the domain being modeled for the FutureGen2.0 project.

Table 4.14. Wireline Logging Program

Depth Interval[a]	Log	Purpose/Comments	Well
Conductor Casing Interval (0 to 140 ft bgs); 30-in. borehole	• No open-borehole logs	• NA	All
	• No cement-bond log	• NA	All
Surface Casing Interval (below conductor casing to 570 ft bgs); 20-in. borehole	• Basic log suite (gamma ray,[b] formation density,[b] neutron porosity,[b] resistivity,[b] spontaneous potential,[b] photoelectric factor, caliper[b])	• Characterize basic geology (lithology, mineralogy, porosity)	Vertical pilot borehole
	• Cement-bond log[b, d]	• Evaluate cement integrity	All
Intermediate Interval (below surface casing to 3,150 ft bgs); 14-3/4-in. borehole	• Basic log suite (gamma ray,[b] formation density,[b] neutron porosity,[b] resistivity,[b] spontaneous potential,[b] photoelectric factor, caliper[b])	• Characterize basic geology (lithology, mineralogy, porosity) • Evaluate borehole condition prior to cementing	Vertical pilot borehole
	• Enhanced log suite (spectral gamma,[c] dipole sonic shear log,[c] resistivity-based and/or acoustic-based image log,[c] nuclear magnetic resonance log,[c] elemental capture spectroscopy log[c])	• Enhanced characterization of geologic and geomechanical properties that control injectivity and confining zone/seal integrity • Dipole sonic log will also provide data to calibrate surface seismic and other purposes	Vertical pilot borehole
	• Cement-bond log[b, d]	• Evaluate cement integrity	All

Depth Interval[a]	Log	Purpose/Comments	Well
Long-String Casing Interval[e] (Vertical borehole, below intermediate casing 3,150 to total depth); 9-1/2 –in. borehole	• Basic log suite (gamma ray,[b] formation density,[b] neutron porosity,[b] resistivity,[b] spontaneous potential,[b] photoelectric factor, caliper[b])	• Characterize basic geology (lithology, mineralogy, porosity) • Evaluate borehole condition prior to cementing	Vertical pilot borehole
	• Enhanced log suite (spectral gamma,[c] dipole sonic shear log,[c] resistivity-based and/or acoustic-based image log,[c] nuclear magnetic resonance log,[c] elemental capture spectroscopy log[c])	• Enhanced characterization of geologic and geomechanical properties that control injectivity and confining zone/seal integrity • Dipole sonic log will also provide data to calibrate surface seismic and other purposes	Vertical pilot borehole
Long-String Casing Interval (Lateral borehole); 9-1/2-in. borehole[f]	• Basic log suite (gamma ray,[b,f] formation density,[b,f] neutron porosity,[b,f] resistivity,[b,f] spontaneous potential,[b,f] photoelectric factor, caliper[b,f])	• Characterize basic geology (lithology, mineralogy, porosity) • Evaluate borehole condition prior to cementing	One or more wells
	• Enhanced log suite (spectral gamma,[c] dipole sonic shear log,[c] resistivity-based and/or acoustic-based image log,[c] nuclear magnetic resonance log,[c] elemental capture spectroscopy log[c])	• Enhanced characterization of geologic and geomechanical properties that control injectivity and confining zone/seal integrity • Dipole sonic log will also provide data to calibrate surface seismic and other purposes	One or more wells
	• Baseline temperature log[b, d] • Cement-bond log[b, d] • Baseline oxygen-activation log (pulsed neutron capture tool) – if it is not run in open borehole[d]	• Determine natural geothermal gradient outside well for comparison to future temperature logs for external mechanical integrity evaluations. • Evaluate cement integrity of long-string casing through confining zone. • Provide baseline measurement for future pulsed-neutron capture logging runs aimed at detecting distribution of CO_2 outside the well for external mechanical integrity evaluations.	All

(a) Well design is described in Section 4.3 of this document; borehole/casing depths are approximate and preliminary.
(b) Required by EPA UIC Class VI permit requirements (10 CFR 146.87).
(c) Optional logs: one or more of these logs may be run across selected intervals of this section of the well.
(d) Cased-hole log
(e) These logs will be run in the vertical pilot borehole.
(f) These logs may be run in the horizontal (lateral) open borehole of one or more injection wells (all are

Depth Interval[(a)]	Log	Purpose/Comments	Well

optional since all required logs will be run in the vertical pilot hole drilled on the same pad as the horizontal injection wells).
NA = not applicable.

4.2.11 Coring

The coring program will provide additional core needed to augment existing core data obtained from the FutureGen 2.0 stratigraphic well that was drilled in late 2011. Selected sections of whole core will be collected from the Mount Simon CO_2 injection zone, the overlying Eau Claire confining zone, and other relevant geologic formations (i.e., Ironton/Galesville, Franconia/Davis, New Richmond, and St. Peter formations) when drilling the vertical pilot borehole for the CO_2 injection wells. Additional whole core will be collected from selected monitoring wells that penetrate the Mount Simon Formation. These additional core sections will be obtained to evaluate spatial variability within the CO_2 injection zone. No additional whole core will be collected when drilling the horizontal injection wells.

Planned laboratory testing of all whole core sections include routine rock property analysis (i.e., porosity, density, permeability) of vertically and horizontally oriented plugs and petrographic analysis (detailed geologic descriptions with supporting thin sections and clay analyses) of each core interval. Special core analysis to obtain important multiphase transport properties (i.e., $scCO_2$-brine relative permeability and $scCO_2$ entrapment) will be performed on selected cores from the Mount Simon Formation, Elmhurst member of the Eau Claire Formation, and the Ironton/Galesville Formation. Additionally, high-pressure mercury injection tests will be performed on all formations from the St Peter Sandstone to the Mount Simon Formation.

Sidewall cores will be collected from all wells to provide a comprehensive set of routine rock property data for calibrating geophysical wireline logs and to supplement formation property data where whole core data are not available.

4.2.12 Hydrologic Testing and Fluid Sampling

Formation fluid sampling and reservoir testing of multiple formations in the intermediate borehole section, as well as an extensive hydrologic testing program within the reservoir will be performed when drilling the vertical pilot borehole for the CO_2 injection wells. This program is designed to provide corroborative and additional hydrologic information about key strata within the injection reservoir and overlying the caprock horizon, including potential monitoring zones (e.g., Ironton), that will support numerical modeling efforts associated with the MVA program.

During drilling and/or during post-completion well development, collection of fluid samples will be attempted in the St. Peter Formation, the New Richmond Formation, the Ironton Formation, and the Mount Simon Formation using a tubing-deployed packer and a submersible pump or an alternate approach method (e.g., wireline-deployed sampling tool such as the Schlumberger Modular Formation Dynamics Tester [MDT]). Formation field fluid parameters (i.e., temperature, pH, conductivity, reservoir pressure, and static fluid level) will be obtained from each sampling event for the hydrologic testing interval. Representative samples from the respective test intervals will be submitted for detailed laboratory analysis and will include major inorganic elements, trace metals, environmental stable isotopes (e.g., C^{13}, O^{18}, H^2), and selected radio-isotopes (e.g., H^3, C^{14}). The field and laboratory analyses will be used to establish baseline data against which future measurements may be compared after the start of injection operations.

Hydrologic tests (e.g., packer, pumping, injection) tests will be conducted to corroborate and expand the level of hydraulic property characterization within the Mount Simon reservoir (i.e., above what already has been obtained from the initial FutureGen 2.0, pilot stratigraphic well [FGA#1]). In addition, hydraulic property field test characterization will be conducted for selected test sections within the primary sealing caprock sections of the overlying Eau Claire.

4.2.13 Geomechanical Testing

An in situ geomechanical characterization program will be conducted in the vertical pilot hole within the Mount Simon Sandstone and the overlying Eau Claire caprock formation using hydraulic fracturing tests to complete the current knowledge of the principal stress conditions for the FutureGen location. The objective of the geomechanical characterization program is to provide information regarding the direction and magnitude of the three principal components of the stress field (σ_h, σ_H, σ_V). In particular, these field geomechanical tests will provide an accurate measurement of the fracture pressure in both the overlying confining zone and the reservoir injection zone. This in situ stress determination program will be accompanied by laboratory measurements of mechanical properties (e.g., tri-axial tests) conducted on selected core samples from the overlying confining/caprock horizon and reservoir injection zone.

Appendix B

IR 01-14-2014_2
IR 01-14-2014_5

Additional Information Regarding

Construction and Operations – Open vs Cased Injection Zone

and

Construction and Operations – Length of Casing in CO_2 Injection Wells

Figures 4.4 and 6.1 of UIC Permit Supporting Documentation

<u>CO_2 Injection Wells Production Casing</u>

Total 7–in.-diameter production casing for cased-hole completion:

3,400-ft carbon steel casing + 2,604-ft or 3,604-ft stainless steel casing = 6,004 ft or 7,004 ft

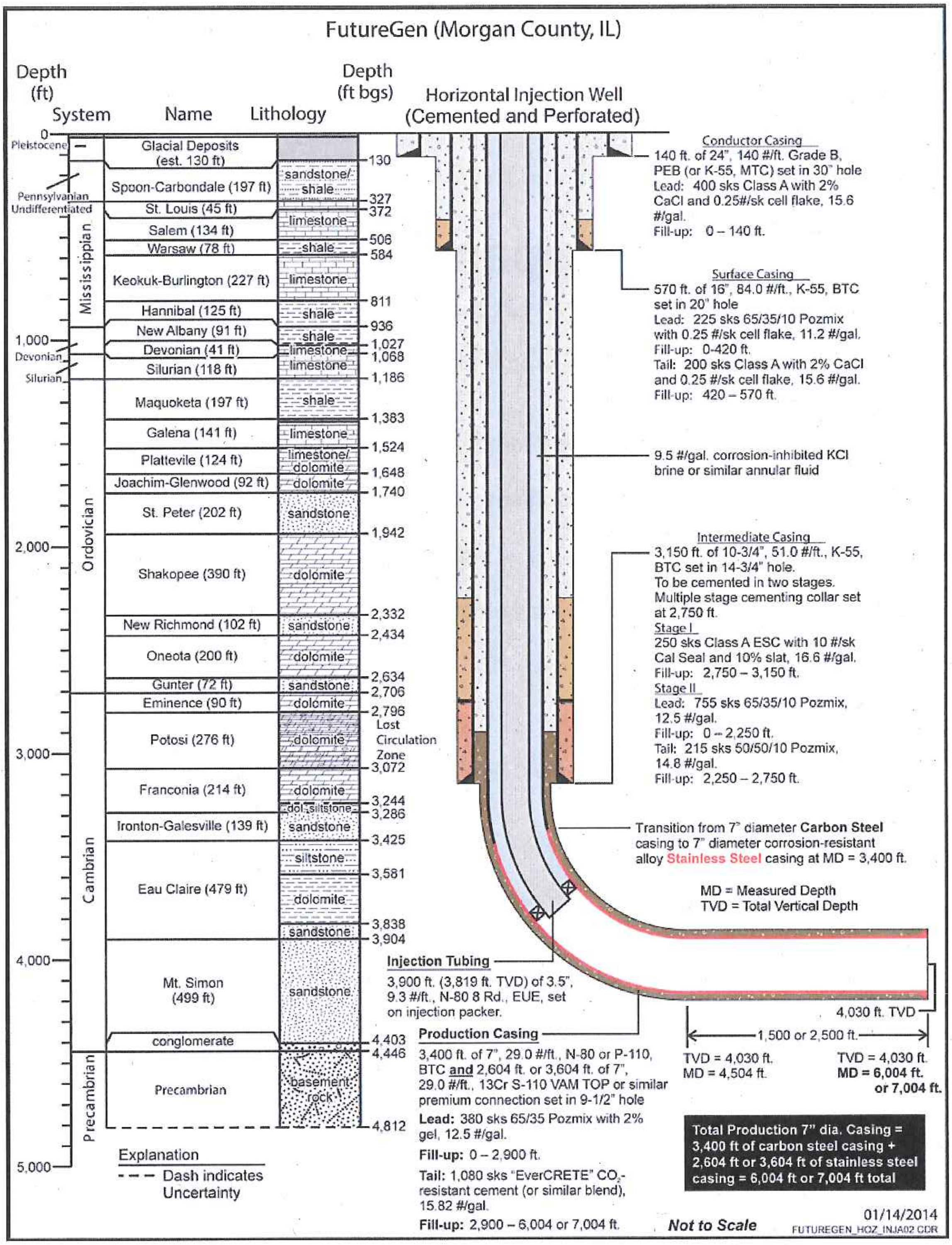

Figure 4.4. Injection Well Schematic – Cased-Hole Completion (geology and depths shown in this diagram are based on site-specific characterization data obtained from the FutureGen 2.0 stratigraphic well)

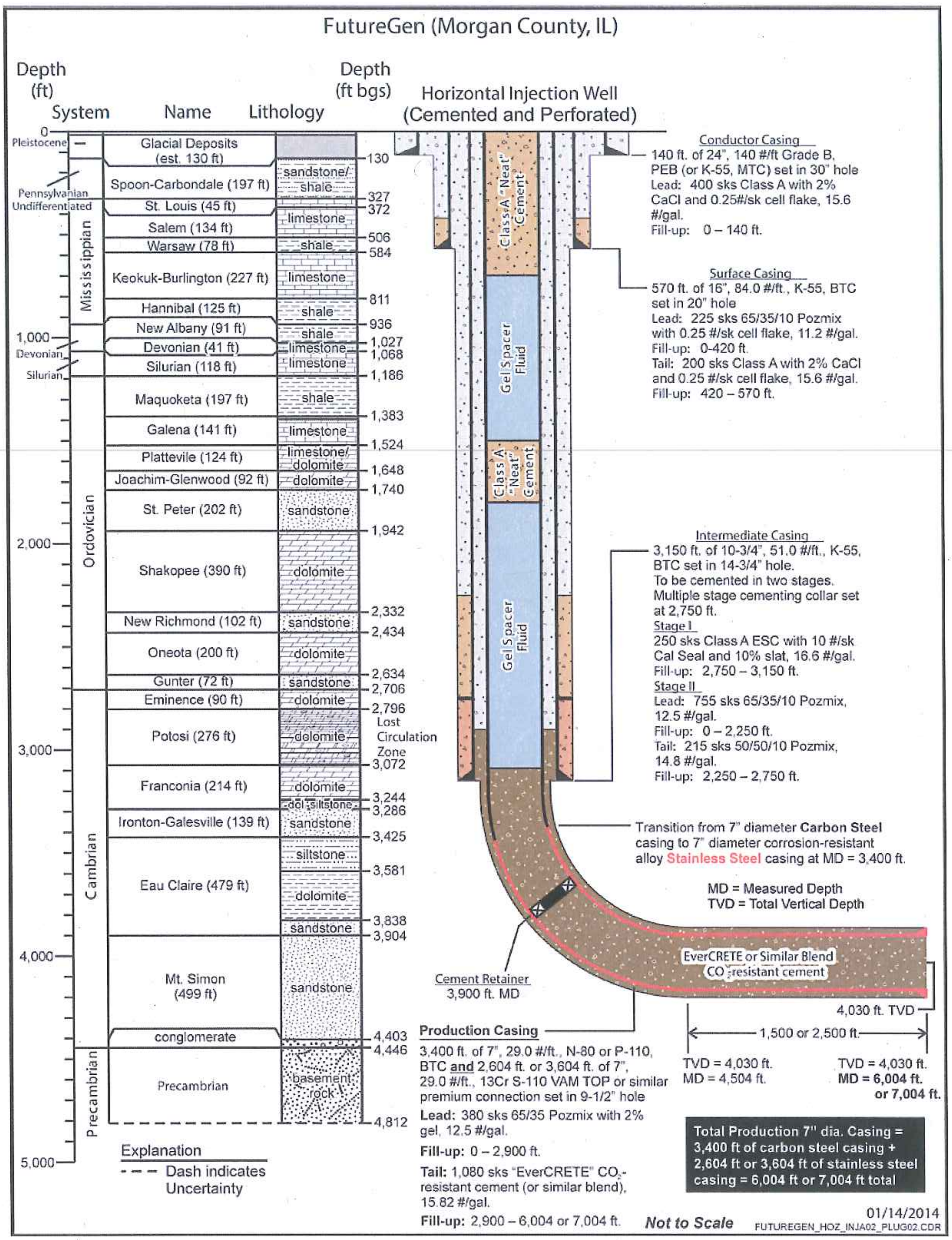

Figure 6.1. Diagram of Cased Injection Well after Plugging and Abandonment